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(54) Measurement method for moisture content in the skin and system therefor.

(57) This invention relates to the measurement of the moisture content retained in the skin, and enables accurate diagnosis of the skin condition by the device, which can be switched in the connection of measurement electrodes to measure the moisture content either in the surface or in the depth of the keratinous layer of the skin.

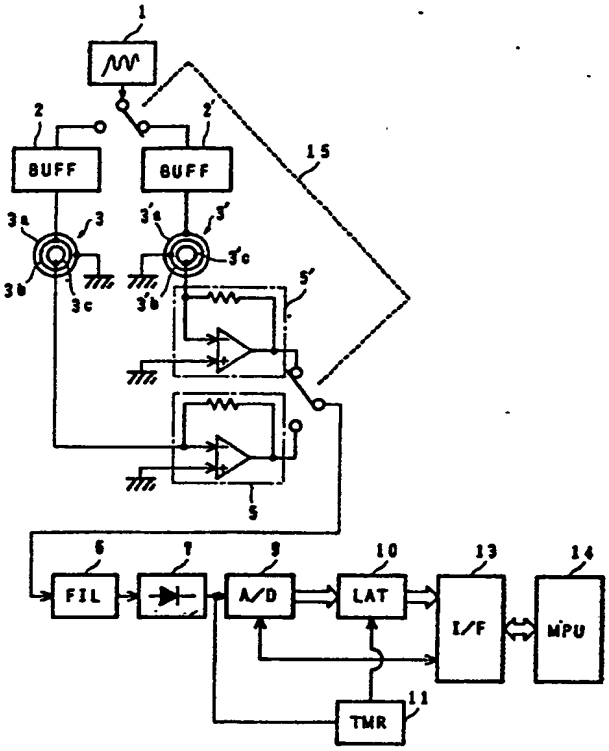
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FIG. 1

This invention is applicable to the measurement of moisture content in the skin.

This invention relates to a method and a device for measuring the moisture content in the human skin or the keratinous layer. More particularly, this invention relates to a method of not only measuring moisture content in the surface of the keratinous layer but also detecting the moisture retained in the deeper layer so as to more accurately learn the conditions of the skin.

Prior Art

There has been known a technology to measure the moisture content in the keratinous layer by sending weak high-frequency current through the human skin and measuring the impedance generated on the skin surface. An equivalent circuit responsive to the high frequency current through the keratinous layer generally comprises parallel circuits of a resistor R and a capacitor C as shown in FIG. 6. When the moisture content in the layer changes, the resistance R and capacity C will change. Detailed description on the above phenomenon is found in, for instance, Reference 1 (Y. Masuda, M. Nishikawa, B. Ichijo, I.E.E.E. Trans. Instrum. Meas. IM 29, No. 1, 28, 1980] and Reference 2 [H: Tanoue, M. Ohi, M. Yamada, The Nishinihon Journal of Dermatology, Vol. 42, No. 4, P. 647, 1980].

The system for measuring these characteristics is a so-called impedance meter which measures the impedance of the equivalent circuit shown in FIG. 6 both in real component and in imaginary component separately.

$$Z = \frac{1}{\frac{1}{R} + j\omega C} \qquad \ldots\ldots (1)$$

As the electrode used in the aforementioned prior art system is a single electrode, operation in measurement is inconveniently cumbersome, and when used to measure the human skin, the measured values fluctuate widely and unstably. As the size of the electrode is small, the scope of measurement is limited to the keratinous layer. In order to obviate such problems, the present inventors proposed a device which has a triple electrode structure, uses low frequency electric current of 3 KHz - 100 KHz, is simple in structure and inexpensive (refer to Japanese Patent Application Disclosure Sho 59-28646), and put it into practice.

Fig. 7 is a block diagram to show the circuit structure of the proposed device wherein the reference numeral 1' denotes a rectangular-wave generator of which output is connected via a buffer circuit 2 to a measuring electrode structure 3 which is to be abutted onto the skin for detecting the moisture content. The measuring electrode structure 3 is constructed in the form of triple concentric circles. An electrode 3a on the outermost circle is grounded as a guard electrode so as to prevent noises induced on the human body. An intermediate electrode 3b is connected to said buffer circuit 2 while a central electode 3c is connected to an amplifier 5. The output from the amplifier 5 is connected to a rectifier 7 via a filter circuit 6. The output from the rectifier 7 is connected to the input of a latch circuit 10 via an AD converter 9. The clock pulse of the latch circuit 10 is given from a timer 11 which is actuated by the output from said rectifier 7 and outputs the clock pulses after a predetermined time. The output from said latch circuit 10 is connected to a digital display circuit 12.

The above described device is operated as follows. The rectangular-wave signals generated by the generator 1' is shaped in waveform by the buffer 2 to stabilize its amplitude before it is given to the measuring electrode 3. The output of the buffer 2 is applied between the electrode 3b and the grounding.

When the measuring electrode 3 is pressed onto the skin at a subject location, potential difference between the electrode 3a on the outermost circle and the central electrode 3c changes due to the moisture content on the keratinous layer, which is detected in terms of voltage and amplified by the amplifier 5. Therefore, the output current from the buffer 2 passes between the electrode 3b and the electrode 3c as shown in FIG. 8, and the potential difference therebetween appears in the output from the amplifier 5. Noises of short period are removed by the filter 6.

The AC voltage filtered by the filter 6 is transformed into DC current by the rectifier 7. The DC current is digitalized by an AD converter 9. The digitalized signals are taken in the latch circuit 10 to be temporarily stored sequentially, and its digital output is displayed at a digital display circuit 12 at a predetermined

timing clocked by the timer 11.

The above mentioned device could measure the moisture content in the keratinous layer with a considerably high precision, but the device is still not fully free of the influence from the conditions on the skin surface. This is partly because the device is adopted to feed low frequency electric current between either one of the group consisting of the central electrode 3c and the intermediate electrode 3b, and the outer electrode 3a; and to measure the electric voltage produced between the other one of the group consisting of said central electrode 3c and the intermediate electrode 3b, and the outer electrode 3a. The current passing through the skin surface between the central electrode 3c and the intermediate electrode 3b is greatly influenced by the voltage.

Purpose of the Invention

This invention was contrived to solve the problems encountered in the prior art and aims at providing a method which can measure the moisture content not only on the keratinous layer but also in the deeper part of the skin for more precise diagnosis of the skin conditions and a device therefor.

Disclosure of the Invention

The first aspect of this invention relates to a method which passes slight low-frequency current from two electrodes abutted onto the skin through the keratinous layer, amplifies the voltage appearing in the layer, takes out the signals of the amplified output after they are rectified, and measures their amplitude to learn the moisture content in the keratinous layer, which is characterized in that the voltage appearing in said keratinous layer is the voltage appearing between another or a third electrode and one of said two electrodes whichever is closer to the third electrode when the third electrode is abutted onto the skin at a location outside the two electrodes.

The second aspect of this invention relates to a measurement device for moisture content in the skin comprising a triple concentric circular electrode structure including a central electrode, an intermediate electrode and an outer electrode which can be abutted onto the skin surface, a generator which uses one of the group consisting of the central electrode, intermediate electrode and outer electrode as a common electrode and supplies low-frequency current between the common electrode and another one of the group of the electrodes, an amplifier which amplifies the voltage appearing between said common electrode and still another electrode of said group of the electrodes, and a means which displays the output voltage from the amplifier which is characterized in that said intermediate electrode is said common electrode.

The third aspect of this invention relates to a measurement device for moisture content in the skin comprising a triple concentric circular electrode structure including a central electrode, an intermediate electrode and an outer electrode which can be abutted onto the skin surface, a generator which uses one of the groups consisting of the central electrode, intermediate electrode and outer electrode as a common electrode and supplies low-frequency current between the common electrode and another one of said electrode group, an amplifier which amplifies the voltage appearing between said common electrode and still another electrode of said group of the three electrodes, and a means which displays the output voltage from the amplifier which is characterized in that a circuit means is provided for switching between the first circuit using said intermediate electrode as said common electrode and the second circuit which uses either one of said central electrode and said outer electrode as the common electrode.

It is preferable to provide two measurement electrodes one of which is connected to the first circuit and the other of which is connected to the second circuit.

Experiments disclosed that when the resistance and capacity which are supposed to change by the moisture content in the keratinous layer are compared to each other, if the low frequency current is selected in the range of 3 KHz to 100 KHz, the resistance is much more influenced than capacity by the changes of moisture content in the range which is assumed to be retained in the human skin. The moisture content in the keratinous layer can be measured to a considerable extent by measuring the absolute value $|Z|$ of impedance obtained from the equation below without the necessity to separate resistance from the capacity.

$$|Z| = \frac{R}{\sqrt{1 + (\omega CR)^2}} \quad \ldots\ldots (2)$$

The voltage which satisfies the equation (2) can be obtained by amplifying the primary voltage and rectifying it.

More specifically, when low-frequency current is supplied between either one of the central electrode and the outer electrode, and the intermediate electrode of the measurement electrode structure of which surface forms substantially concentric triple circular electrodes and which can be abutted onto the skin, a voltage is generated between the other one (or the one not selected above) of the central electrode and outer electrode, and the intermediate electrode. Almost all the current flowing on the skin surface runs to the intermediate electrode without influencing the voltage generated between the intermediate electrode and the above mentioned other electrode. The current flowing in the depth of the keratinous layer runs toward said other electrode to greatly influence the voltage generated between the intermediate electrode and said other electrode of the central and outer electrodes. The moisture content in the depth of the layer can therefore be measured from the voltage.

The device may be equipped with measurement electrodes of different circuits which can be switched by a switch so that the moisture content in both the surface and the depth of the keratinous layer can be detected.

As described in the foregoing statement, this invention enables measurement of moisture content in the depth of the keratinous layer of so as to learn the general moisture retention and retaining function of the keratinous layer as a whole.

If the whole measurement device according to this invention is made portable, it can be easily used without much trouble even by laymen without knowledge or expertise on the device.

The device is further advantageous if equipped with two types of electrodes of different circuits which are shifted with a switch, as it can be used to measure the moisture content in the layers both relatively close to the surface and relatively deep.

Brief Description of Drawings

FIG. 1 is an electric circuit diagram to show an embodiment of this invention,

FIG. 2 a diagram to show the structure and connection of measurement electrode structure used for the embodiment of this invention,

FIG. 3 a perspective view to show the embodiment of this invention and

FIG. 4 a graph to show characteristics in moisture detection in a test using water permeable membrane.

FIG. 5 is a graph to show the characteristics of moisture detected on the human skin,

FIG. 6 an equivalent circuit diagram on the keratinous layer,

FIG. 7 a circuit diagram of a prior art device and

FIG. 8 a diagram to show the structure and connection of the prior art measurement electrodes.

The reference numerals denote the following components:

1	sine wave generator	1′	rectangular wave generator
2,2′	buffer circuits	3,3′	measurement electrodes
3a,3′a	outer electrodes	3b,3′b	intermediate electrodes
3c,3′c	central electrodes	5,5′	amplifiers for detecting voltage
6	filter circuit	7	rectifier
9	AD converter	10	latch circuit
11	timer	12	digital display
13	interface	14	computer
15	switch	51,52	measurement electrodes

Preferred Embodiments

This invention will now be described in more detail referring to an embodiment shown in the attached drawings. FIG. 1 is a circuit diagram of an embodiment of this invention wherein the reference numeral 1 denotes a sine wave generator of which output is connected to a measurement electrode structure 3 for measurement of the moisture content on the surface of keratinous layer or a measurement electrode structure 3′ for measurement of the moisture content on the depth thereof by abutting them onto the skin via a switch 15 and a buffer 2 or 2′. The measurement electrode structures 3,3′ are respectively connected to amplifiers 5,5′.

Description will now be given to the case where the moisture contained in the depth of the keratinous layer is detected. The electrode structure 3′ is structured to define triple concentric circles having a central electrode 3b′ which is earthed as a guard electrode in order to eliminate the effect of the electric current flowing through the keratinous layer. To an outer electrode 3a′ of the electrode structure 3′ is connected a buffer 2′ while an amplifier 5′ is connected to a central electrode 3c′. The output from a rectifier 7 is connected to the input of a latch circuit 10 via an AD converter 9. The clock pulse from the latch circuit 10 is fed from a timer 11 which is actuated with the output from said rectifier 7 to start output after a predetermined time. The output from the latch circuit 10 is connected to a computer 14 via an interface 13.

The operation of the device having the aforementioned structure according to this invention will now be described. The sine wave signals generated at the sine wave generator 1 are shaped in the waveforms thereof by the buffer 2′ and stabilized in amplitude, and are fed to the measurement electrode 3′. The output from the buffer 2′ is applied between the electrode 3a′ and the ground. The voltage to be applied in the measurement electrode 3′ is set at a level less than 3 V or the level low enough not to be sensed by men. The frequency of the electric current generated by the generator 1 is selected from the range of 1 - 50 KHz or preferably from the range of 10 - 30 KHz so as to avoid polarization due to the moisture in the skin.

When the measurement electrode 3′ is abutted on the skin being tested, the potential difference between the intermediate electrode 3′b and the central electrode 3′c changes due to the moisture content in the deeper keratinous layer, and the voltage detected is amplified at the amplifier 5′. Therefore, the output current at the buffer 2′ flows between the electrode 3′a and the electrode 3′c and this potential difference appears at the output of the amplifier 5′. Noises of short period are removed by the filter 6.

The AC voltage filtered by the filter 6 is transformed into DC voltage by the rectifier 7. The DC voltage corresponding to the peak value rectified by the rectifier 7 is counter-proportionate to the absolute value $|Z|$ of the impedance of the deeper keratinous layer.

The DC voltage is digitalized by an AD converter 9. The digitalized signal is latched by a latch circuit 10 consecutively to be registered temporarily, and the digital output therefrom is outputted at a predetermined timing clocked by the timer 11 to the computer 14 via an interface 13. The timing can be selected arbitrarily from the time when the electrode is abutted on the skin until the time when the measured value becomes stable. It is preferably 1 - 20 sec., and is, for instance, 5 seconds.

The computer 14 stores statistical data and compares the digital output which has been inputted with the statistical data.

A switch 15 is a means to switch the first circuit which uses the intermediate electrode 3′b as the common electrode and which is connected to the amplifier 5′ and the second circuit which uses either one of the central electrode 3c and the outer electrode 3a as the common electrode and which is connected to the amplifier 5. By switching the switch 15, the moisture content on the surface keratinous layer can be detected. The structure and operation of the measurement is similar to the description made in relation to the prior art.

FIG. 13 is a perspective view of this invention measurement device. When the electrode 51 having the first circuit of the connection 3′c(R) - 3′b(G) - 3′a(S) and the central electrode 3′b as the common electrode is abutted on the skin, it can measure the moisture content of the deep keratinous layer while the measurement electrode 52 having the second circuit of the connection 3c(R) - 3b(S) - 3a(G) and either one of the central electrode 3c and the outer electrode 3a as the common electrode is abutted on the skin and measures the moisture content in the surface keratinous layer.

By manipulating the switch, the moisture content can be measured both in the deep layer and the surface layer of the keratinous layer to thereby enable more accurate diagnosis of the skin conditions.

FIG. 4 is a graph to show moisture sensing characteristics. In simulation, five sheets of water permeable membrane (paraffin paper) were piled, and water was charged beneath the piled membranes. The characteristics were measured by closely attaching measurement electrodes 51 and 52 on the paper sheets.

The graph shows that as the water permeated, the measured value of the moisture content increased. The graph also reveals that the electrode 51 of this invention system could detect the same value in shorter time than the prior art electrode 52, indicating that the moisture in deeper layer was detected.

FIG. 5 is a graph to show the moisture detecting characteristics obtained from a test on the human skin. In the test dry gas (N_2 gas) was being blown onto the keratinous layer, and the moisture content was measured by the electrodes 51 and 52 which were attached closely on the skin.

The result of the test revealed that the effect of the dry gas was felt earlier in the case when the prior art electrode 52 was used than when this invention electrode 51 was used indicating that this invention system is less susceptible to the dry gas and can detect the moisture in the deeper keratinous layer of the skin.

Although the above embodiment connects the output from the buffer 2′ to the outer electrode 3′a of the measurement electrode 3′ and the input thereof is connected to the amplifier 5′ of the central electrode 3′c, the central electrode 3′c and the outer electrode 3′a may be interchanged to have a similar effect. Although in the above embodiment, the filter 6 is connected to the output of the amplifier 5′, it may be provided on the other side of the circuit 5 where low frequency current is supplied to the measurement electrode 3′.

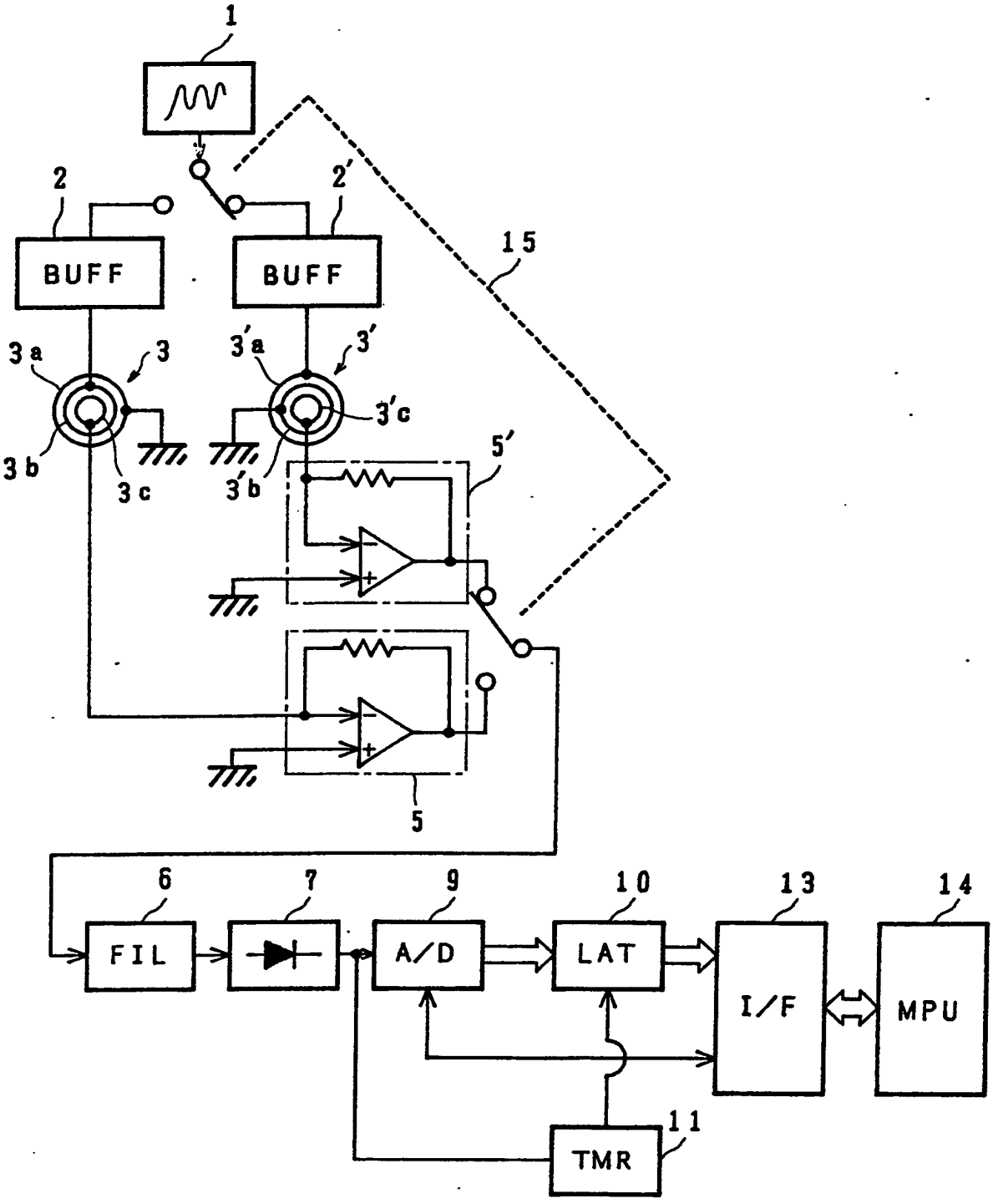
Claims

1. A method for measuring moisture content in the skin by passing weak low frequency electric current through the keratinous layer from two electrodes abutted upon the skin, amplifying the electric voltage appearing on the layer, rectifying and taking out signals of the amplified output, and measuring the amplitude of the signals, which is characterized in that the voltage appearing on the keratinous layer is the voltage appearing between either one of said two electrodes whichever is closer to another electrode which is abutted upon said skin at a location outside of said two electrodes.

2. A system for measuring moisture content in the skin comprising
a measurement electrode structure of triple concentric circles including a central electrode, an intermediate electrode and an outer electrode all of which can be abutted on the skin on the surface thereof,
a generator which uses one of the group consisting of said central electrode, intermediate electrode and outer electrode as a common electrode and supplies low frequency current to between this common electrode and another one of the group of said three electrodes,
an amplifier which amplifies the voltage appearing between said common electrode and still another one of said group of the three electrodes,
and a means to display the output voltage of the amplifier,
which is characterized in that said intermediate electrode is said common electrode.

3. A system for measuring moisture content in the skin comprising,
a measurement electrode structure of triple concentric circles including a central electrode, an intermediate electrode and an outer electrode, all of which can be abutted on the skin on the surface thereof,
a generator which uses one of the group of said central electrode, intermediate electrode and outer electrode as a common electrode and supplies low frequency current to between this common electrode and another one of said group of three electrodes,
an amplifier which amplified the voltage appearing between said common electrode and still another one of said group of three electrode,
and a means to display the output voltage of the amplifier, especially as claimed in claim 2,
which is characterized in that a circuit is provided for switching between the first circuit having said intermediate electrode as said common electrode and the second circuit having either said central electrode or said outer electrode as said common electrode.

4. The system for measuring moisture content in the skin as claimed in Claim 3 wherein the measurement electrodes are provided in the number of two, one of which is connected to the first circuit and another one of which is connected to the second circuit.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3'b
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LAT
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TMR
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FIG. 1

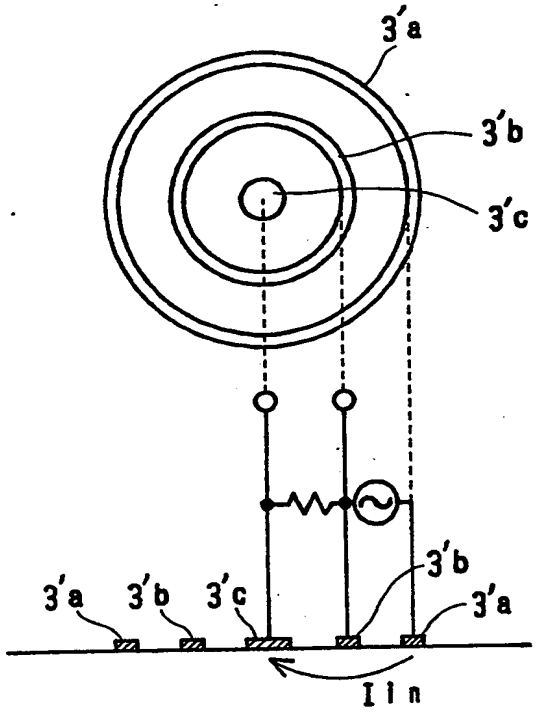


FIG. 2

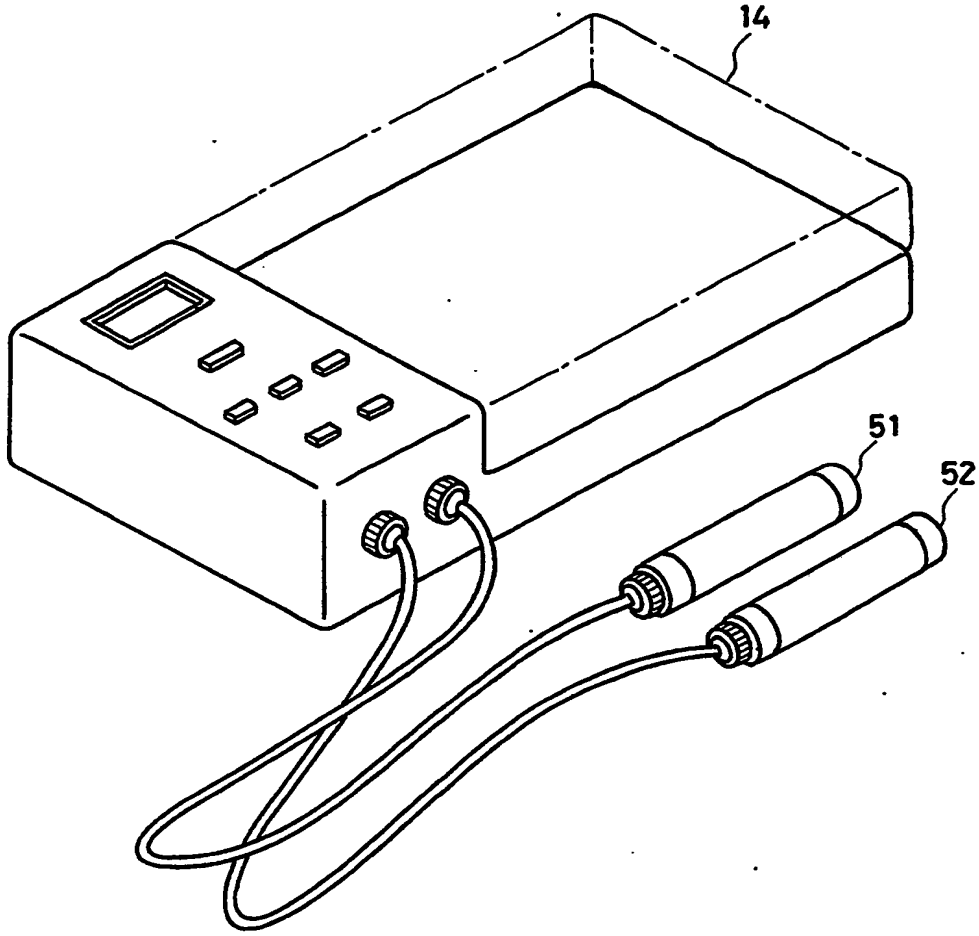


FIG. 3

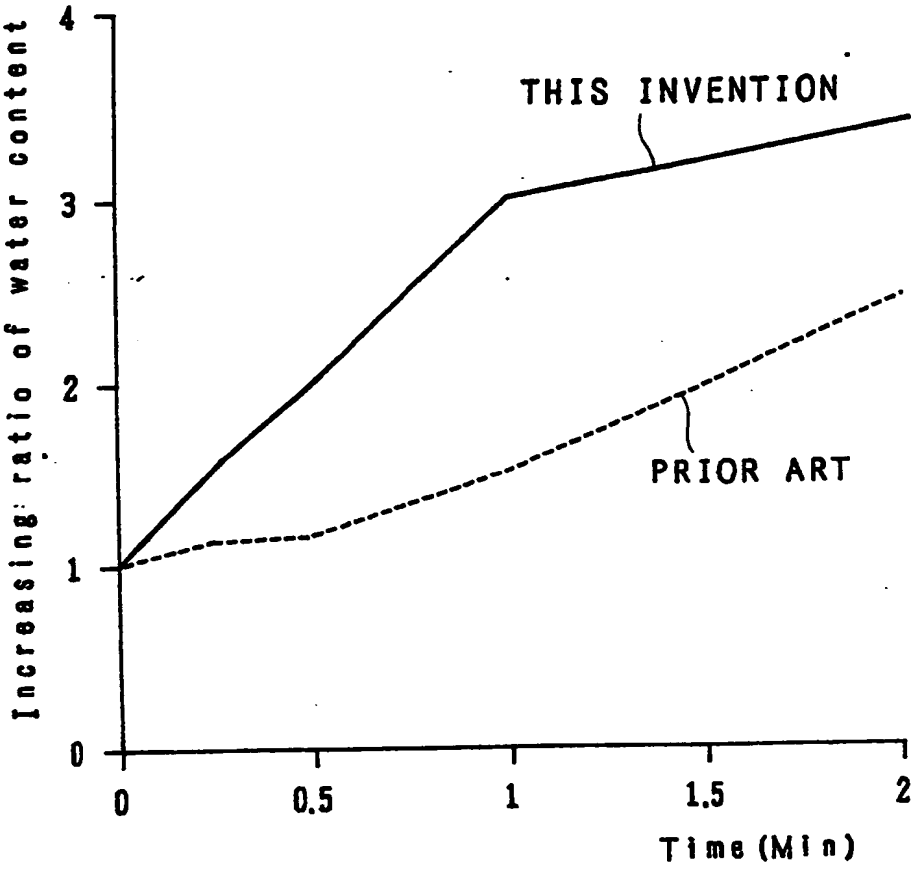

Increasing ratio of water content
4
3
2
1
0
0
0.5
1
1.5
2
Time (Min)
THIS INVENTION
PRIOR ART

FIG. 4

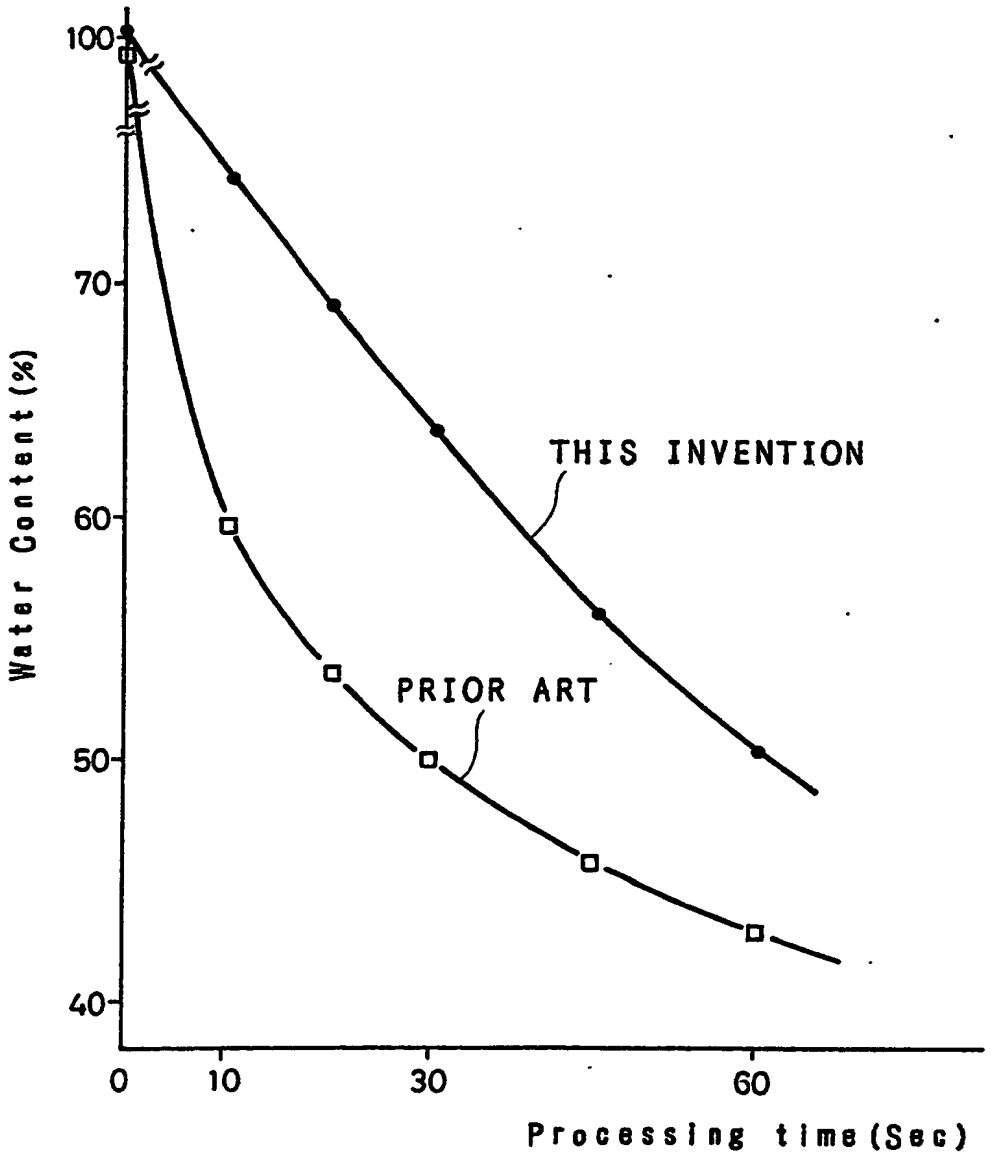

100
70
60
50
40
Water Content (%)
THIS INVENTION
PRIOR ART
0
10
30
60
Processing time (Sec)

FIG. 5

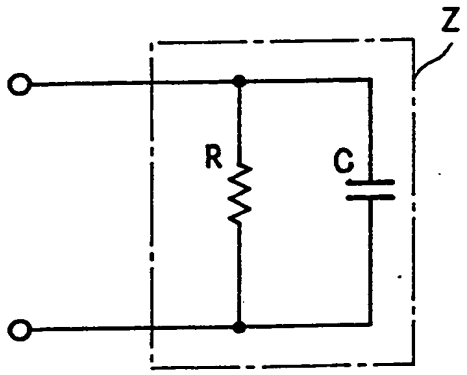


FIG. 6

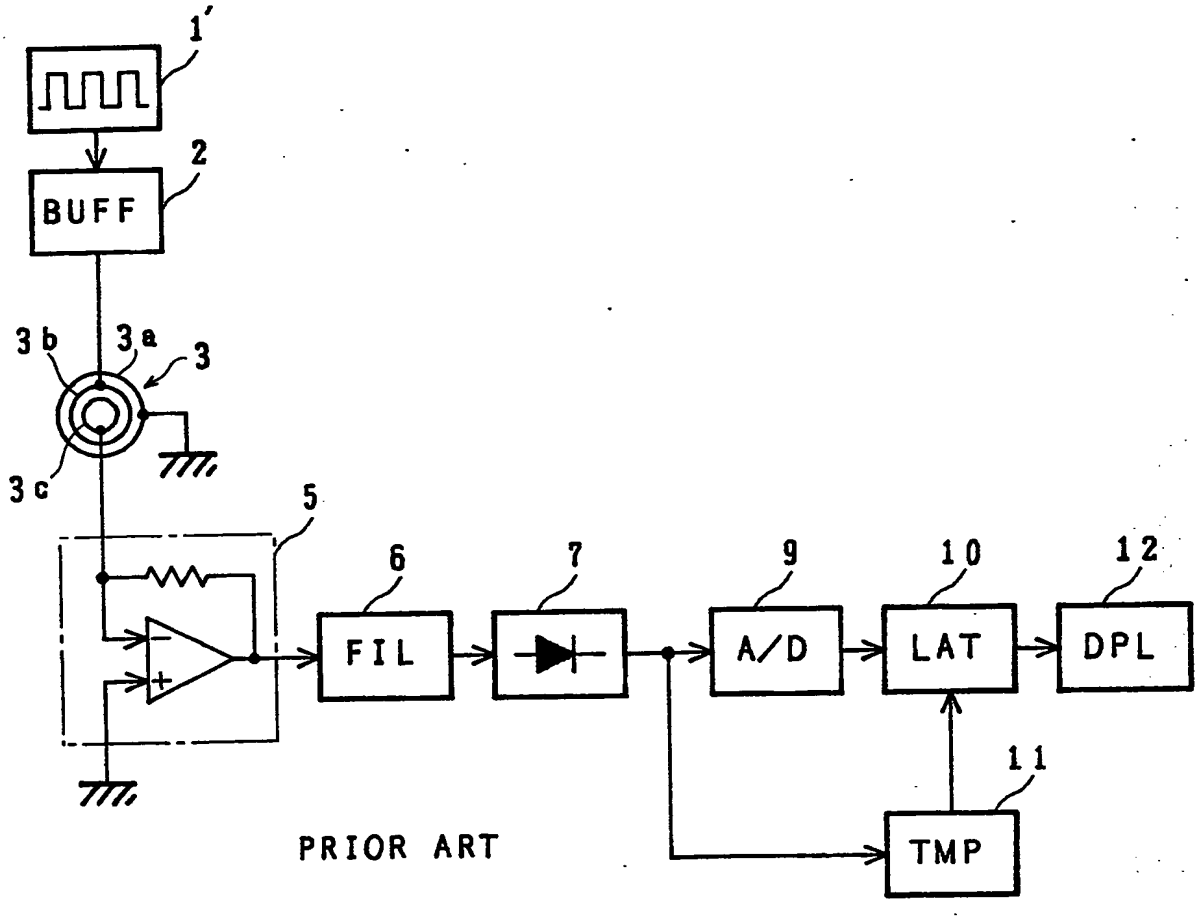
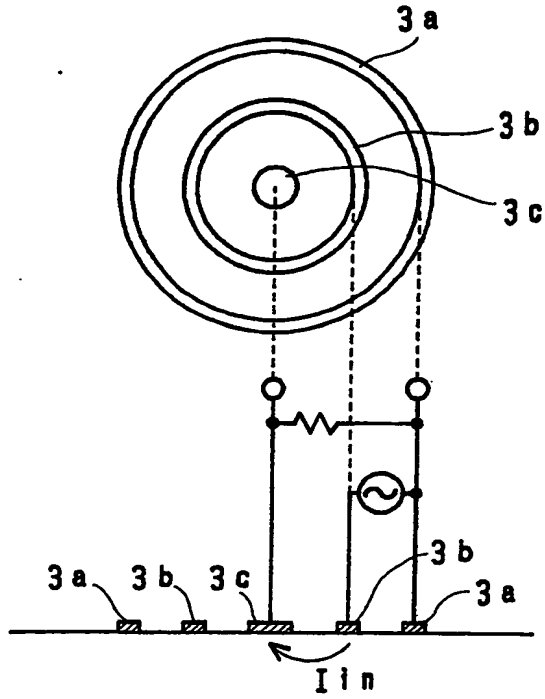


FIG. 7



PRIOR ART

FIG. 8

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 88 11 8083

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
D,A	PATENT ABSTRACTS OF JAPAN, vol. 8, no. 125 (P-279)[1562], 12th June 1984; & JP-A-59 28 646 (KAO SEKKEN K.K.) 15-02-1984		A 61 B 5/10

TECHNICAL FIELDS SEARCHED (Int. Cl.4)

A 61 B
G 01 N

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	20-02-1989	CHEN A.H.

CATEGORY OF CITED DOCUMENTS

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